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Better Ways to Preserve Wisconsin's Concrete Bridges

from research to reality

BRIEF

RESEARCH DEVELOPMENT & TECHNOLOGY TRANSFER

One of the most serious threats to the highway system throughout the United States is deterioration of concrete bridge decks. Wisconsin's more than 9,700 bridges are no exception. The most frequent culprit is chloride, usually from road deicing chemicals, or road salt, but also sometimes found within the concrete itself. The chloride eats away at the bridge's reinforcing steel. That makes the steel expand, cracking the concrete and shortening the life of the bridge.

Many techniques have been developed to test for deterioration in concrete without having to physically damage the structures. Half a dozen of these nondestructive testing (NDT) methods are used in Wisconsin. These include techniques as simple as listening to the sounds of a hammer when specific bridge sections are struck or the sounds of a chain as it is dragged across the bridge's surface. More sophisticated techniques include ground penetrating radar that produces detailed images of materials deep within the bridge structures and infrared thermography that pinpoints hidden concrete delaminations.

Maintenance engineers also have several types of treatment from which to choose. In some cases it may be best to apply a layer of concrete to the bridge surface; that is currently the most common way to treat bridge decks. In other cases, an asphalt layer may be a better choice. And in others yet, an asphalt-and-concrete surface supported by a membrane may be the treatment of choice.

What's the Problem?

Determining the extent of chloride damage on individual bridges can be difficult. Even more challenging is the task of deciding in a systematic way which bridges to repair, what rehabilitation strategies to use and when to use them—in order to optimize the overall system in the most cost-effective way.

WisDOT engineers would like to improve their current guidelines for maintaining concrete bridge decks. They are looking for a more systematic approach that would help quantify existing strategies and offer new alternatives. Of the state's 9,700 plus bridge decks, more than 7,000 remain untreated. While many of these will not need treatment anytime soon, thanks to the use of epoxy coated steel and other technologies, a significant number will need treatment action in the coming years to extend their useful lives. Officials begin to be concerned about any concrete bridge deck older than 15 years, and the average Wisconsin bridge deck is 20.

Research Objectives

The primary goal of this project was to develop a tool—in the form of a spreadsheet—that would help engineers account for the effects of chloride on bridges' steel reinforcement, predict how long a particular bridge deck is likely to last and select the best course of treatment to make it last longer.

Study Design and Results

First the researchers studied the different ways that WisDOT district personnel test bridge decks for chloride damage. The researchers sent questionnaires to all eight transportation district offices. The questionnaire asked engineers not only which NDT techniques they currently use to search for concrete flaws but also which techniques they were considering using in the future. The researchers also reviewed existing engineering and scientific literature on 14 different NDT methods and they studied other scientists' models for predicting how bridges deteriorate and for how to treat them.

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Bridge performance curves with and without treatment using a concrete overlay.

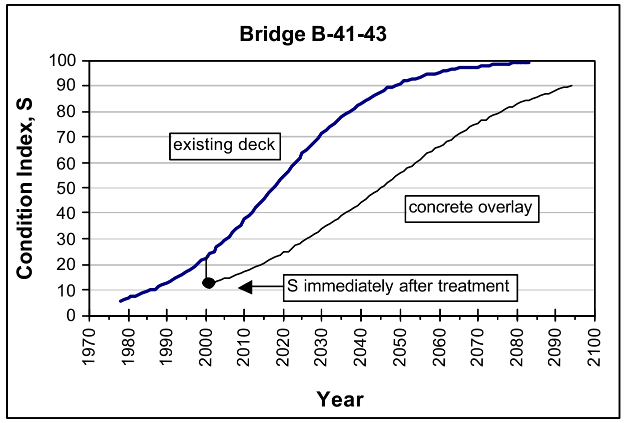

Figure 9. Performance curves, before and after the treatment

"This tool will help us make better decisions on which bridges to focus on, how best to extend their useful life and how to do it most economically."

- Stan Woods, Structures Development Chief, WisDOT Bureau of Structures

The researchers used one of the previous models—developed in 1996 by Babaei, Purvis, Clear, and Weyer for the US DOT—as the foundation of their new model, a spreadsheet tool they named BridgeDeck-LCCA (life cycle cost analysis). The spreadsheet constructs a performance curve for existing bridge decks, computes the estimated service life of common treatments for bridge decks (such as patching and concrete or asphalt overlays) as well as the service life of a new deck with epoxy-coated bars. The spreadsheet then calculates a life cycle cost analysis for common maintenance scenarios and determines the optimal maximum (tolerable) condition index that minimizes total life cycle maintenance cost.

The research team also examined eight strategies for maintaining bridge decks, including traditional methods of patching faults and laying down new sections as well as more cutting-edge techniques. In the newer methods, layers of broken concrete are removed, then the chlorides are attacked, either by being extracted chemically or being sprayed with chloride inhibiting chemicals. Another strategy is to provide cathodic protection to the steel reinforcements by passing a continuous current through them.

Further Research and Implementation

More detailed data in some areas would make the model even more effective. Currently, state engineering records lump together two types of deck faults, spalling, in which the concrete chips, and delamination, in which the concrete layers separate. But these faults represent different stages in the deterioration of a deck. The research team suggested that spalling and delamination in decks be recorded separately. Because the chloride content near the steel bars is critical to the deterioration of a deck, the team suggests that engineers measure and record chloride content on bridges they are inspecting. And until that can be accomplished, they suggest creating a database of estimated chloride levels.

It would also be useful if some of the nondestructive testing methods and treatments were better understood. The team recommended studying two NDT techniques—infrared thermography and ground penetrating radar—to evaluate the consistency of their results. The team also suggested using the spreadsheet tool to evaluate three treatments—chloride extraction, corrosion inhibitors, and cathodic protection—that currently aren't used in Wisconsin.

Benefits

Combined with the strategies and techniques the research team provided, the new BridgeDeck-LCCA spreadsheet they developed will help district bridge engineers compute how a bridge deck will perform, estimate how well different repair strategies would work, and calculate the long-term costs of different maintenance plans.

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Assessment and Rehabilitation Strategies/ Guidelines to Maximize the Service Life of Concrete Structures

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